Next Generation Networking Overview
15 Sept 2005

Preston Marshall
preston.marshall @darpa.mil

Defense Advanced Research Projects Agency
Advanced Technology Office

Wireless Network After Next

Rescue Radio

Radio-Isotope Micro-power Sources

Retro-Directive Noise Correlating Radar

Connectionless Networks

Wolfpack

One of DARPA's top 5 programs!
·Defense News, June 3, 2002

Polarization Rotation Modulation

Photonic Avionics

Disruption Tolerant Networks

Delay Tolerant Networking

XG
Next Generation Communications

DARPA XG Program

All Spectrum May Be Assigned, But…

…Most Spectrum Is Unused!

Maximum Amplitudes

Heavy Use   Heavy Use

Sparse Use   Medium Use

Amplidue (dBm)

Frequency (MHz)
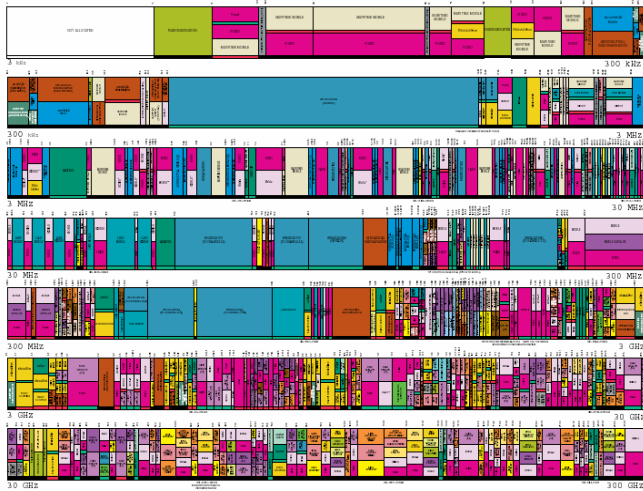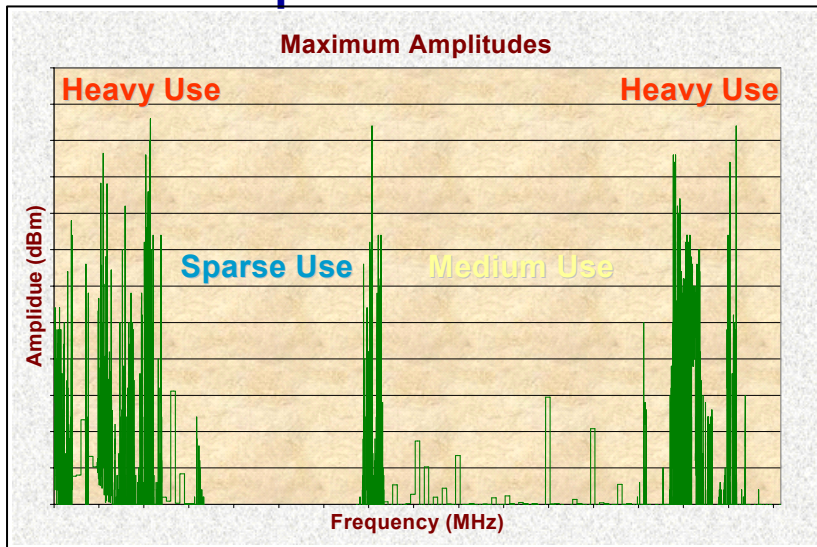
XG is Developing the Technology and System Concepts for DoD to Dynamically Access All Available Spectrum

Sense — Real time, Low-power, wideband monitoring

Characterize — Rapid waveform determination

React — Formulate Best Course of Action

Adapt — Transition network to new emission plan

Autonomous Dynamic Spectrum Utilization
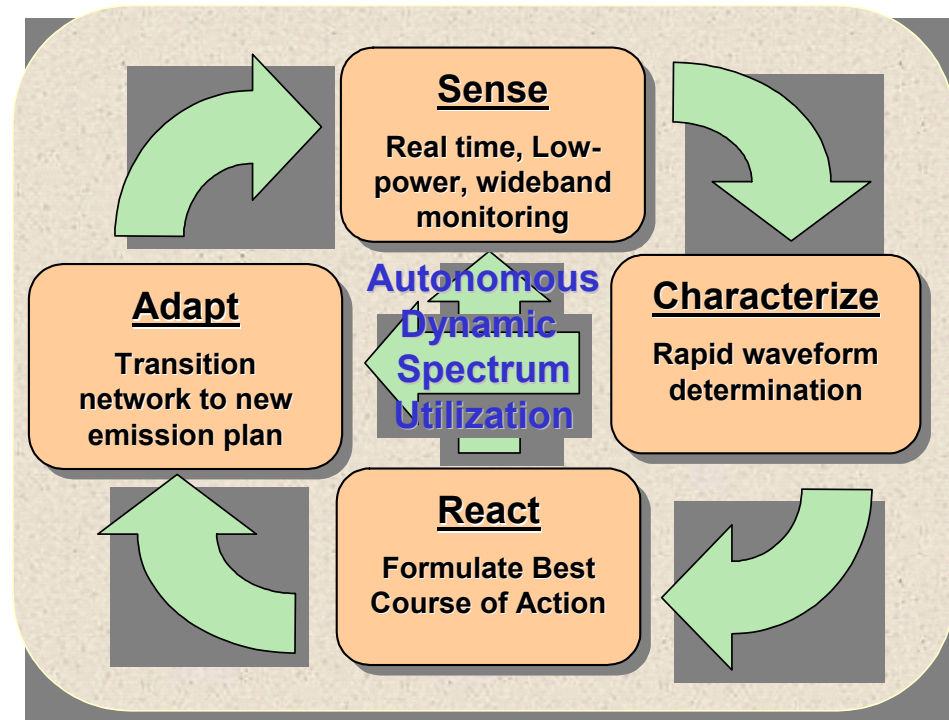
Goal: Demonstrate Factor of 10 Increase in Spectrum Access

XG Program Aspects

Measurements

Policy-Based Controls

Temporal, Spectr...
Dimensional, Ener...
Characterist...

Control of Features,
Priorities, Allocations,
Exclusions,…

XG Products

XG Behaviors

Military & Civil
Communications and
Sensor Applications

Initial XG Implementation

Transition to
Military Use
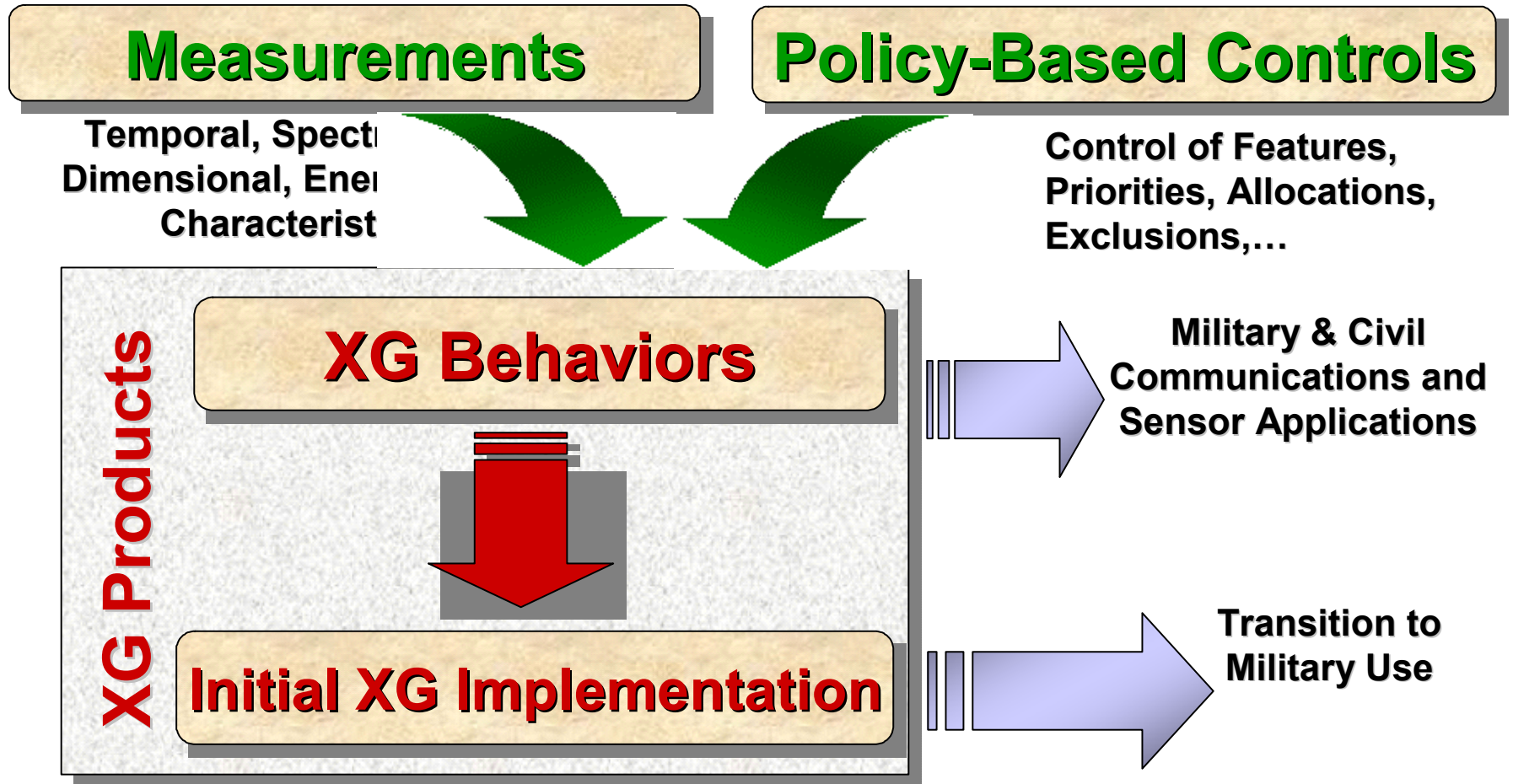
The Primary Product XG Program is **Not a New Radio**, but a **Set of Advanced Technologies** for Dynamic Spectrum Access
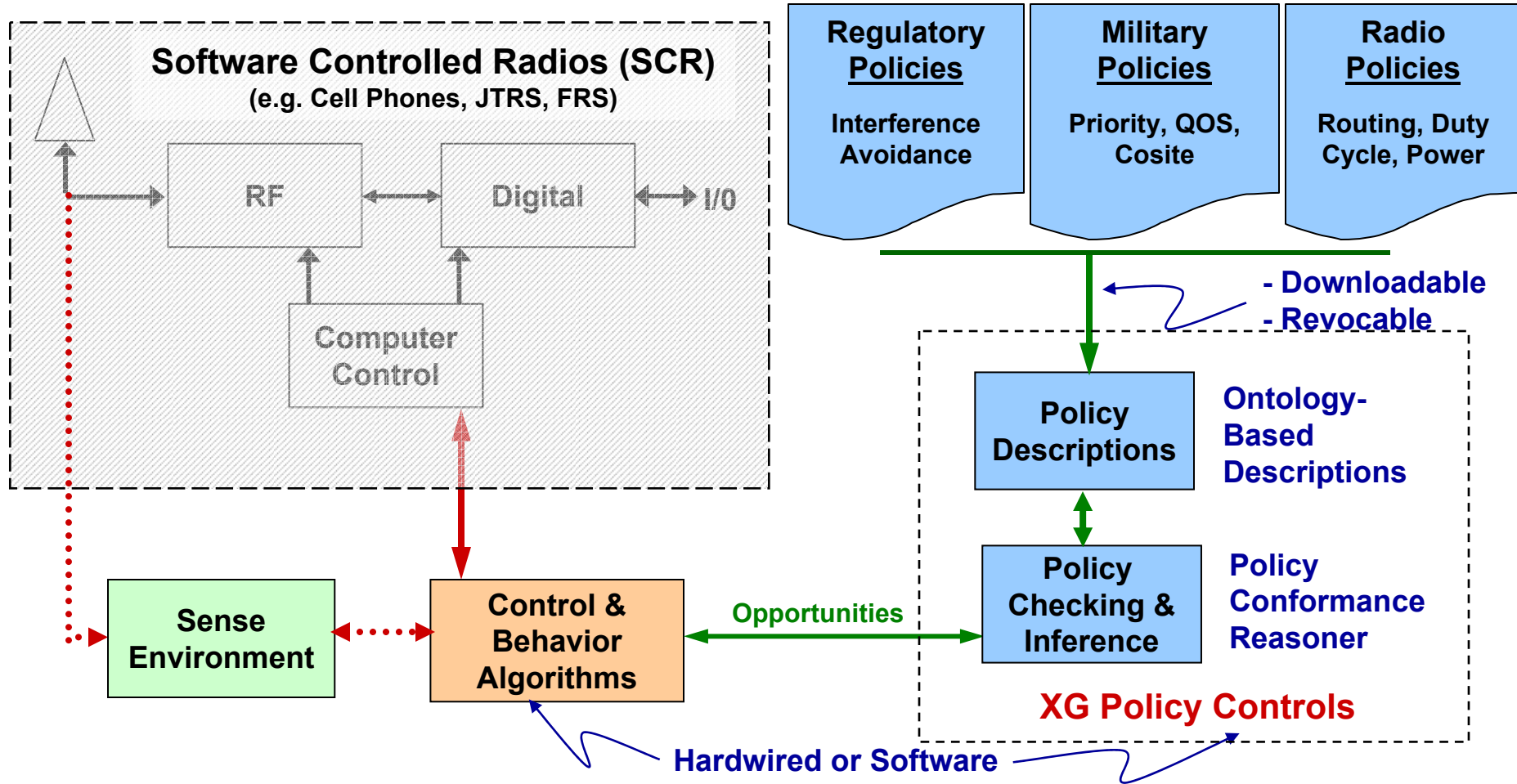
XG Key Principles

- **Suitable for Range of Architectural Implementations**
  - **Centralized And Decentralized**

- **Identify "Interference-Preventing" Core Set**
  - **Flexible with Respect to Desired Interference Threshold(s)**
  - **Extensible To Other Features (Subleasing, Microcharging,...)**

- **Separate Policies From Engineering**
  - **Avoid Advocacy For Specific Sharing Policies**
  - **XG Being Developed In Advance of Policy Framework**

- **Provide For Richness/Complexity of Policies**
  - **Regulations Neither Flat Nor Hierarchical**

- **Allow For Diversity of Policy Sources**
  - **Peer-Peer And Hierarchical Policy Authorities**
  - **Enable Extension To "Cognitive" Optimizing Logic**

> **Policy "Layer" Flexible for Implementations to Use Without Revisiting for Engineering & Policy Changes**
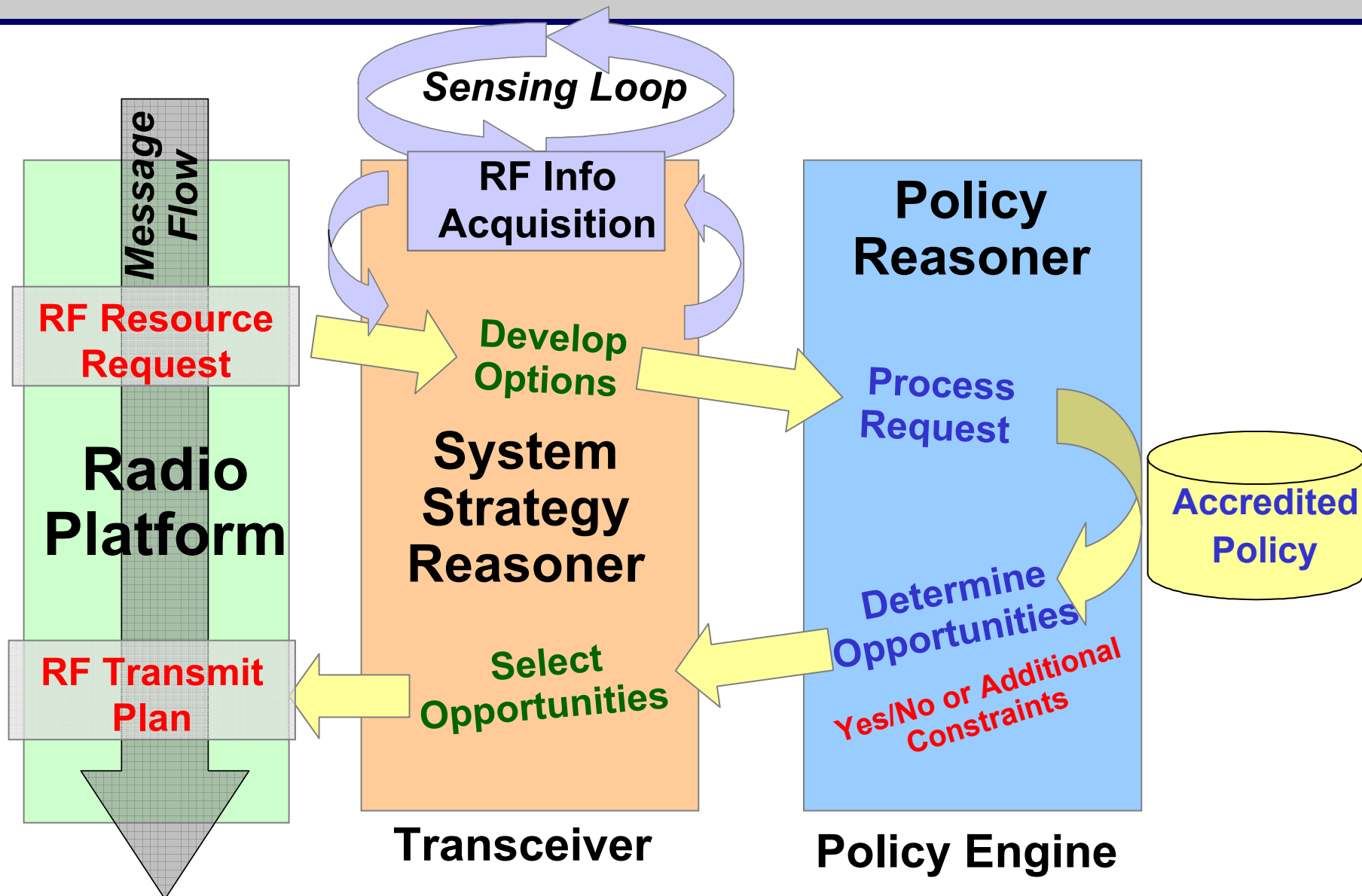
XG – Program Components

Software Controlled Radios (SCR)
(e.g. Cell Phones, JTRS, FRS)

RF ↔ Digital ↔ I/0

Computer Control

Sense Environment

Control & Behavior Algorithms

Regulatory Policies

Interference Avoidance

Military Policies

Priority, QOS, Cosite

Radio Policies

Routing, Duty Cycle, Power

- Downloadable
- Revocable

Policy Descriptions

Ontology-Based Descriptions

Policy Checking & Inference

Policy Conformance Reasoner

Opportunities

XG Policy Controls

Hardwired or Software

The Primary Product XG Program is Not a New Radio, but The Critical Technologies for Dynamic Military Access to Spectrum

XG Operation

Sensing Loop

Message Flow

RF Info Acquisition

Policy Reasoner

RF Resource Request

Develop Options

Process Request

Radio Platform

System Strategy Reasoner

Accredited Policy

Determine Opportunities

RF Transmit Plan

Select Opportunities

Yes/No or Additional Constraints

Transceiver

Policy Engine

XG Sensor

- **XG Sensor Focuses on Capabilities and Features Needed for JTRS C-1 Transition**
  - **Significantly smaller footprint (more than 3X volume reduction)**
    - **RF card is 2X2 inches**
  - **Continuous frequency coverage 30 MHz – 2.5 GHz (vs. 6 bands)**
    - **Only 1 filter for 30 MHz – 1 GHz**
  - **Low power devices reduced power to 1 W average**
  - **Fast FFT frame rate**
    - **1 mSec, 8192 bins x 14 bits**

- **Enhanced Digital Architecture**

- **Will be Deployed in Phase 3 Prototypes**
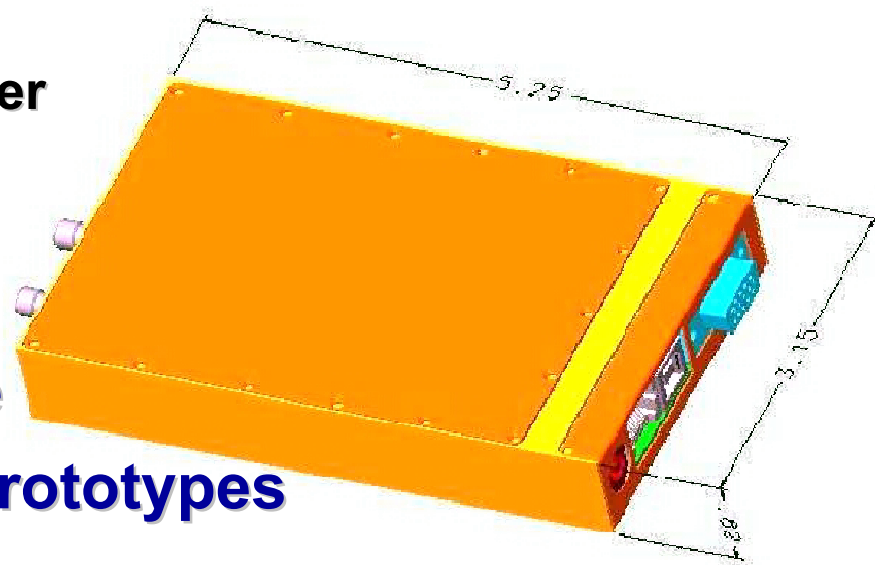
XG – Phase 2 Significant Findings

- **All Signals are Not Created Equal**
  - **Understanding of Temporal Characteristics Is Necessary**
  - **Need to Detect Below Noise Floor**
  - **Interference Avoidance Policies Specific to Detected Signal**
- **Degree of A Priori Knowledge of Signals Provides Significant Performance Enhancement**
  - **Difference in Detecting Known vs. Unknown Signals in Noise Affects How Aggressively XG Can Access Spectrum**
  - **Allocation Tables Provide A Priori Knowledge of Expected Signal Types, Especially Fixed and Broadcast**
- **Policy Reasoning Necessary for Range of Incumbent Signal Protection**
  - **Commercial Services Are Sensitive to Effects of Interference at Many Levels, Including Reception Quality, BER, and Increase in Transmitter Power**
  - **Military Signals Are Inherently Hardened and Tolerant of Interference**
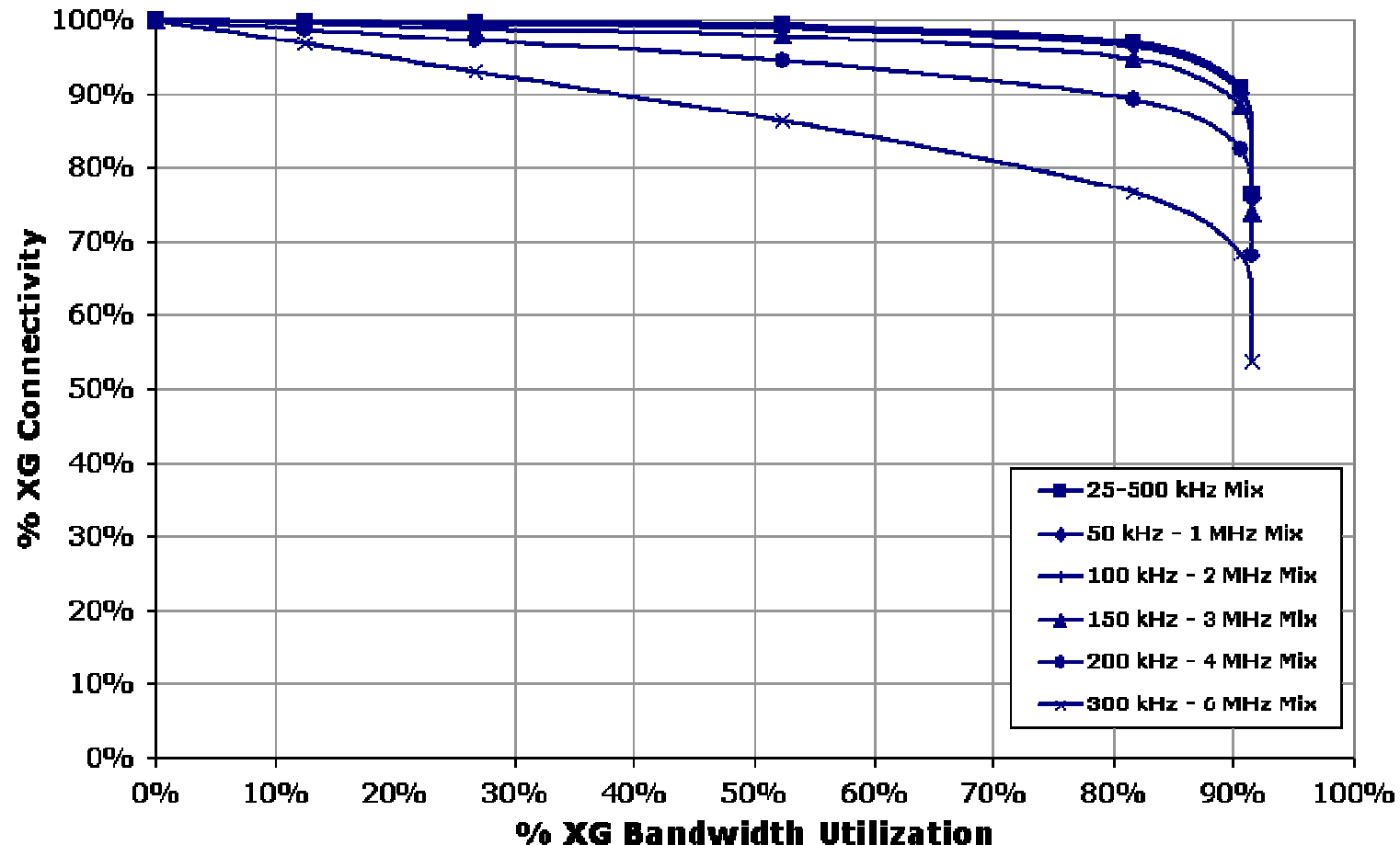 - **Agile Systems Can Even Move If Interference Occurs**

XG Spectrum Access vs. Network Connectivity
- Mixed Bandwidths -

Legend:
- 25-500 kHz Mix
- 50 kHz - 1 MHz Mix
- 100 kHz - 2 MHz Mix
- 150 kHz - 3 MHz Mix
- 200 kHz - 4 MHz Mix
- 300 kHz - 6 MHz Mix

X-axis: % XG Bandwidth Utilization
Y-axis: % XG Connectivity

Data from Lockheed Martin, Raytheon, and Shared Spectrum Company models

- **Build XG Technologies in Prototype Radio**
  - Integrate The Radio, Adaptation Algorithms, Sensor Components, Policy-based Controls, And Radio Software into SCA Traceable Prototype
- **Continue Developing Key Policy Control Technologies**
- **Conduct Early Incremental Field Demos**
  - Build Confidence in XG Capabilities Though A Series of Demos
    - Increase capability and environmental complexity at each demo
  - Implement Networks Of Spectrum-agile Radios Which Dynamically Adapt To Changing Spectrum Environments
  - 10x More Spectrum Without Interference To Non-XG Radios
  - Demonstrate And Validate The XG Prototype's Capabilities In Representative Military And Urban RF Environments.
- **Transition to Military Program of Record In FY07**